Build-a-Planet

Astronomy 5205 SP22

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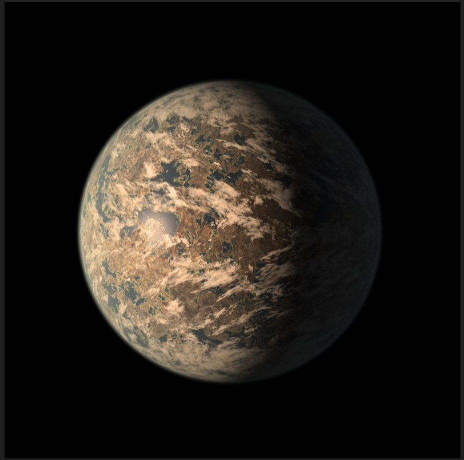
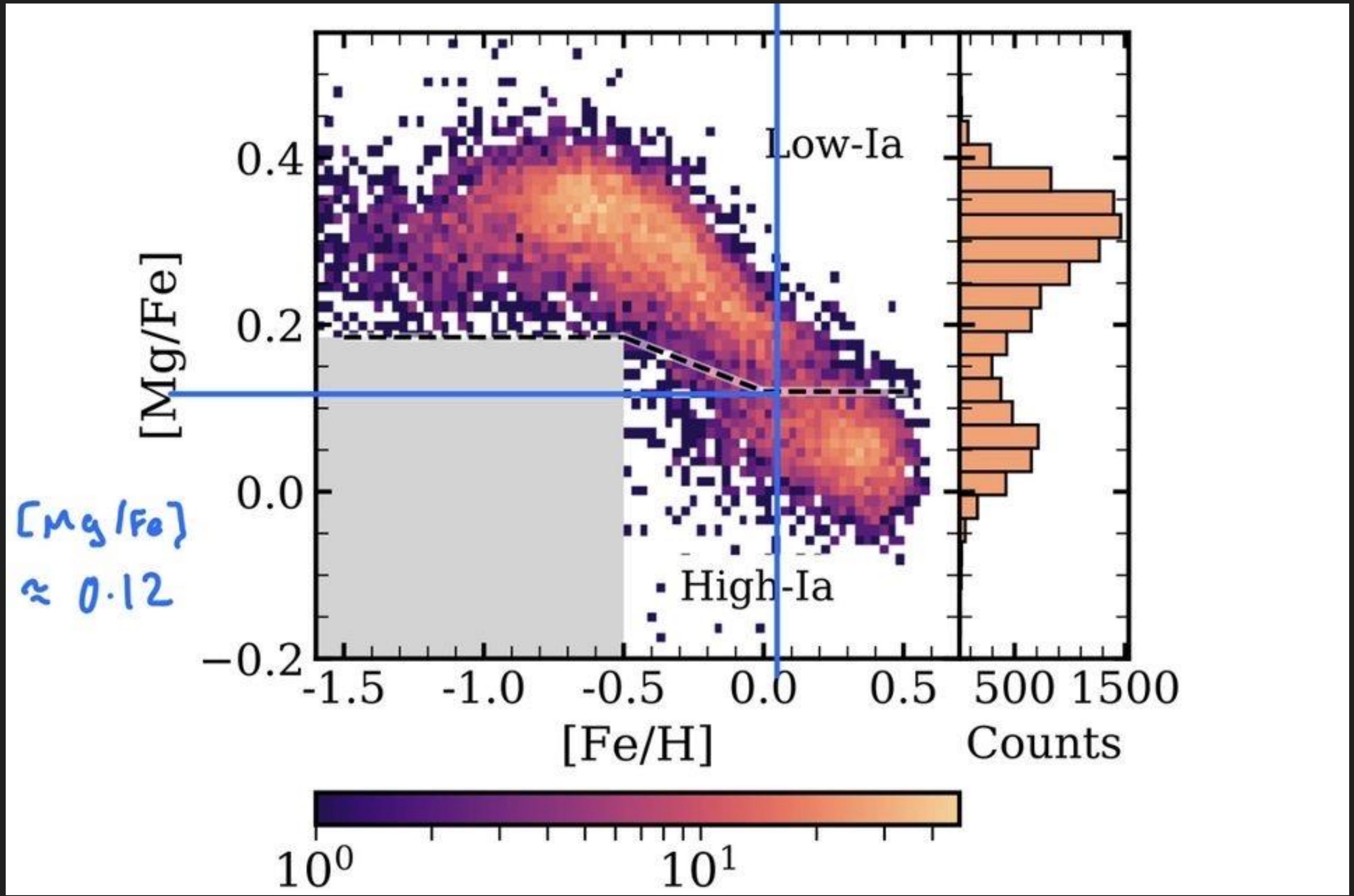
1. Motivations

- Calculate a planet's possible density and structure.
- Calculate planet structures from mass-proportions and compare them to stellar.
- Place the structure and composition in context of mineral proportions and orbital parameters.

2. Methods



- Planet: Trappist 1e
  - 0.91 Earth Radii (NASA)
  - 1.02 Earth Density (NASA)
  - 0.93 Earth Gravity (NASA)
- [Fe/H]: 0.040 + 0.080 (Gillon et. al 2017)
- Mass: 0.772 +0.079 /- 0.075 Earth Masses (Grimm et al. 2018)



Low-Ia
High-Ia
[Mg/Fe]
[Fe/H]
Counts
0.4
0.2
0.0
−0.2
-1.5
-1.0
-0.5
0.0
0.5
500
1500
10^0
10^1
[Mg/Fe] ≈ 0.12

Calculations

- [Mg/Fe] = 0.12
- Fe/Mg = 0.683
- [Fe/Mg] = -0.12 ~ -0.134
- [Si/Mg] = -0.017
- Si/Mg = 0.86

$$[Mg/Fe] = \log\left(\frac{Mg/Fe}{(Mg/Fe)_{\odot}}\right)$$

- Mass = 0.772 Earth radii

Table 2. Same as Table 1, but for APOGEE DR16+ Fe-peak elements, Cu, and Ce

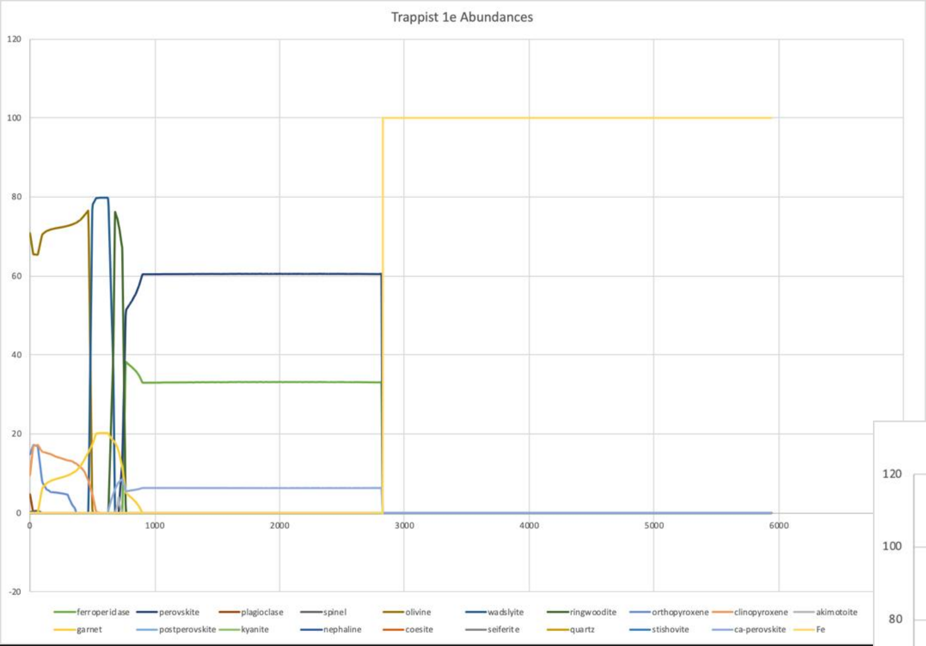
[Mg/H]	[V/Mg]	[Cr/Mg]	[Fe/Mg]	[Mn/Mg]	[Co/Mg]	[Ni/Mg]	[Cu/Mg]	[Ce/Mg]
-0.262	0.015	0.001	–	–	-0.069	-0.030	–	–
-0.149	0.005	0.006	0.040	-0.200	-0.032	-0.026	-0.045	–
-0.043	-0.004	-0.012	0.020	-0.127	-0.049	-0.031	-0.032	-0.075
0.056	-0.002	-0.021	0.013	-0.063	-0.040	-0.018	-0.003	-0.070
0.153	-0.001	0.005	0.045	-0.030	-0.021	0.005	-0.013	-0.140
0.255	-0.004	0.024	0.057	0.025	0.001	0.021	0.010	-0.187
0.354	-0.009	0.041	0.068	0.082	0.032	0.051	0.057	-0.190
0.445	-0.026	0.058	0.066	0.133	0.074	0.071	0.065	-0.198
0.532	-0.041	0.072	0.052	0.145	0.106	0.082	0.105	-0.204
-1.254	-0.049	-0.001	-0.406	-0.620	-0.443	-0.247	0.169	-0.237
-1.145	-0.033	-0.052	-0.410	-0.614	-0.429	-0.254	0.151	-0.273
-1.042	-0.014	-0.114	-0.414	-0.639	-0.403	-0.248	0.142	-0.251
-0.95	-0.015	-0.171	-0.361	-0.622	-0.309	-0.230	0.097	-0.259
-0.844	-0.004	-0.166	-0.366	-0.612	-0.303	-0.216	0.047	-0.172
-0.746	-0.031	-0.154	-0.304	-0.594	-0.264	-0.210	-0.016	-0.118
-0.646	-0.056	-0.187	-0.328	-0.590	-0.268	-0.223	-0.069	-0.123
-0.547	-0.066	-0.153	-0.291	-0.566	-0.238	-0.211	-0.116	-0.181
-0.444	-0.084	-0.141	-0.270	-0.535	-0.191	-0.202	-0.121	-0.244
-0.345	-0.104	-0.168	-0.280	-0.510	-0.194	-0.203	-0.140	-0.291
-0.248	-0.114	-0.152	-0.272	-0.490	-0.164	-0.189	-0.160	-0.331
-0.149	-0.119	-0.131	-0.258	-0.443	-0.146	-0.175	-0.172	-0.333
-0.049	-0.120	-0.130	-0.242	-0.383	-0.126	-0.160	-0.166	-0.316
0.046	-0.120	-0.125	-0.219	-0.342	-0.112	-0.141	-0.164	-0.290
0.142	-0.105	-0.113	-0.197	-0.256	-0.101	-0.116	-0.126	-0.233
0.241	-0.088	-0.080	-0.183	-0.157	-0.078	-0.097	-0.087	-0.206
0.345	-0.075	-0.048	-0.174	-0.107	-0.055	-0.065	-0.092	-0.255
0.445	-0.080	-0.039	-0.134	–	-0.042	-0.043	–	–

Table 1. Median high-Ia (top) and low-Ia (bottom) sequences for APOGEE DR16+ α-elements and light-Z elements. We calculate medians in bins with a width of 0.1 dex in [Mg/H], requiring > 20 stars per bin. Zero-point shifts discussed in Section 4.1 are included.

[Mg/H]	[O/Mg]	[Na/Mg]	[Al/Mg]	[Si/Mg]	[P/Mg]	[S/Mg]	[K/Mg]	[Ca/Mg]
-0.262	-0.044	0.002	–	-0.085	-0.018	0.022	0.025	–
-0.149	-0.017	0.019	-0.041	-0.036	-0.004	0.022	0.022	0.048
-0.043	-0.022	0.008	-0.090	-0.003	-0.018	0.014	-0.006	-0.028
0.056	-0.012	0.005	-0.044	0.013	-0.017	0.002	-0.029	-0.017
0.153	0.001	-0.003	0.012	0.025	-0.017	-0.004	-0.034	0.007
0.255	0.008	-0.010	0.081	0.026	-0.018	-0.027	-0.041	0.020
0.354	0.013	-0.020	0.170	0.023	-0.014	-0.056	-0.051	0.065
0.445	0.010	-0.030	0.230	0.019	-0.014	-0.070	-0.057	0.073
0.532	-0.000	-0.043	0.266	0.003	-0.021	-0.091	-0.069	0.094
-1.254	-0.264	-0.011	–	-0.527	-0.015	-0.190	0.231	-0.056
-1.145	-0.232	0.011	–	-0.468	0.015	-0.062	0.199	-0.005
-1.042	-0.244	0.017	–	-0.411	0.016	-0.200	0.283	-0.031
-0.95	-0.226	-0.005	–	-0.377	0.011	-0.201	0.234	-0.028
-0.844	-0.229	-0.017	–	-0.314	0.019	-0.216	0.233	-0.047
-0.746	-0.246	-0.043	–	-0.233	0.000	-0.273	0.161	-0.058
-0.646	-0.270	-0.053	–	-0.211	-0.007	-0.281	0.153	-0.079
-0.547	-0.269	-0.056	–	-0.211	-0.032	-0.266	0.110	-0.086
-0.444	-0.270	-0.056	–	-0.213	-0.066	-0.221	0.077	-0.085
-0.345	-0.274	-0.056	–	-0.165	-0.060	-0.173	0.078	-0.069
-0.248	-0.269	-0.051	-0.188	-0.128	-0.063	-0.134	0.044	-0.060
-0.149	-0.255	-0.045	-0.201	-0.096	-0.069	-0.113	0.016	-0.044
-0.049	-0.230	-0.040	-0.185	-0.062	-0.064	-0.084	-0.004	-0.036
0.046	-0.197	-0.030	-0.153	-0.040	-0.061	-0.076	-0.016	-0.028
0.142	-0.152	-0.025	-0.119	-0.017	-0.059	-0.069	-0.043	-0.030
0.241	-0.126	-0.029	-0.094	0.001	-0.060	-0.070	-0.072	-0.030
0.345	-0.103	-0.051	-0.020	-0.004	-0.056	-0.067	-0.076	0.014
0.445	-0.086	-0.071	0.024	-0.017	-0.065	-0.139	-0.106	0.019

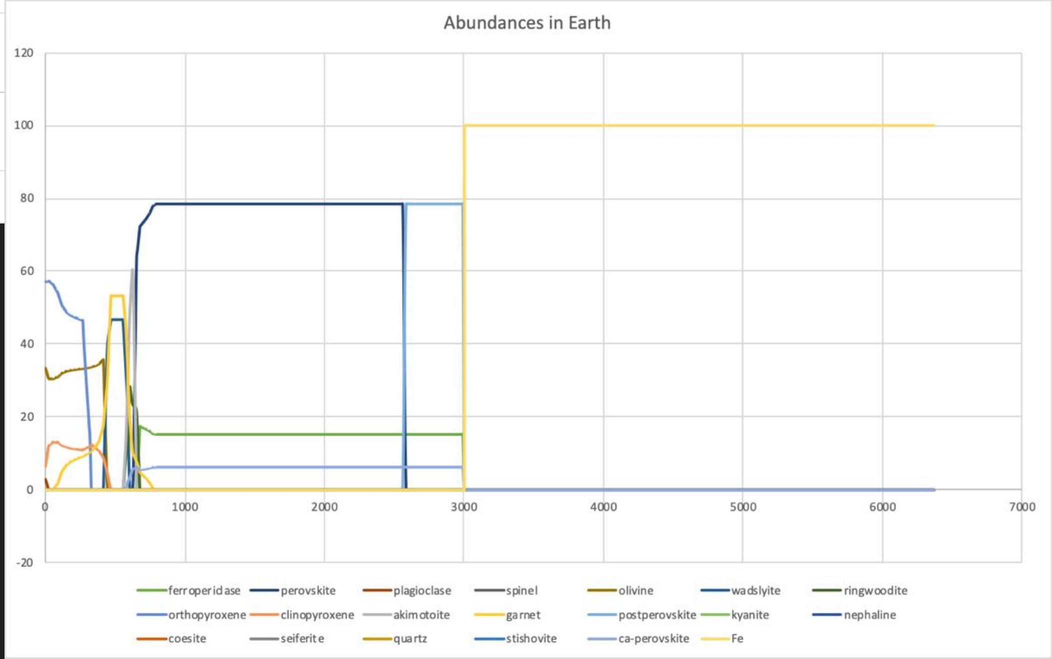
3. Results

- Si/Mg=0.86
- Fe/Mg=0.75
- mol fraction Fe in mantle = 0.004
- fraction of Si in core = 0.021
- fraction of S in core = 0.005
- fraction of O core = 0.005
- Radius = 0.932 Earth radii (Actual value = 0.91 (NASA))
- Density ~ 5.06 g/cm^3 (Actual value ~ 5.61 (NASA))



Trappist 1e:

Earth:



4. Conclusions

- trappist is terrestrial and has similar mineral composition to earth
- the metallicity and elemental abundance of a planet’s star has a huge impact on the abundance of its surrounding planets
- the molar ratio of Fe/Mg and the other factors we can put into exoplex greatly affect the planet’s radius and core/mantle ratio

Citations

- Fulton et al., 2017
- Seager et al., 2007
- Chen and Kipping, 2016
- Griffith et al., 2020
- https://exoplanets.nasa.gov/trappist1/